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United States Department of Agriculture
Bureau of Entomology and Plant Quarantine

METHYL BROMIDE FUMIGATION OF IMPORTED PERISHABLE FOOD PRODUCTS

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INTRODUCTION

During the winter months of 1938, 1939, and 1940 large quantities of perishable food products imported into this country were fumigated with methyl bromide for the destruction of certain insect pests. The results of these treatments, some of which themselves provided the experimental data upon which recommendations for treatment were based, are presented herewith. Commercial fumigations were performed principally at New York, N. Y., or Havana, Cuba, with a few at Seattle, Wash. Supplementary experimental tests were made at New York, Havana, San Juan, P. R., and Washington, D. C. The following food products were treated: Green pod vegetables, including green lima beans, string beans, and pigeon peas (gandules); cipollini bulbs (Muscari comosum), chestnuts, grapes, and peaches.

The experimental tests were all made by the writer, with the aid and cooperation of foreign-plant quarantine inspectors, various importers, the Seccion de Sanidad Vegetal de la Secretaria de Agricultura de Cuba, and the Asociacion de Cosecheros y Exportadores de Frutas y Vegetales de Cuba. The Cuban-American Terminal Company of Havana, Cuba, also cooperated in experimental studies made in a fumigating plant they erected at Havana.

Max Kisliuk, Jr., in charge of the New York office of the Division of Foreign Plant Quarantines, and Herman G. Frank, inspector in that office, gave invaluable aid in the performance of the tests, as did W. A. McCubbin, in charge of the San Juan office of the same division, and others. C. A. Reed, of Nut Investigations, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, assisted in examining chestnuts for quality following fumigation. The Division of Forest Pathology, Bureau of Plant Industry, provided chestnuts for studies of the effect on quality and insect control.

GREEN POD VEGETABLES

Problem

Green pod vegetables imported into the United States during winter months from the West Indies (Cuba and Puerto Rico) have frequently been found infested with larvae of Maruca testulalis, a bean pod borer occurring throughout that area but not known within continental United States. Cuban green pod vegetables were formerly examined in Havana by inspectors of Sanidad Vegetal, and reexamined by inspectors of the Division of Foreign Plant Quarantines upon arrival at New York. This method was of doubtful efficiency. Accordingly, in the 1938-39 shipping season shipments in which any infestation was discovered were refused entry. This caused losses to importers, as some infested shipments were found each week, and also raised the question as to whether inspection was a sufficient safeguard, since the occurrence of live larvae in some of the shipments each week would indicate that all shipments might be lightly infested.

Insect-Mortality Studies

An arbitrary selection of a dosage calculated to be high enough to cause complete mortality of all Maruca testulalis larvae at dock temperatures was made on the basis of previous experience, and a test fumigation was made with infested shipments of green lima beans after preliminary trials had shown this product to be uninjured by treatment. The dosage rate chosen was 4 pounds of methyl bromide per 1,000 cubic feet of space, including the load, for a period of 90 minutes in a partial vacuum of 15 inches, sustained for the duration of the treatment.1/ The beans were made available to the Bureau for experimental studies by importers in an effort to salvage the shipments. After fumigation a number of hampers of beans were reinspected, and when no live larvae were found the beans were considered free from hazard and allowed entry.

The same experimental procedure was followed for infested shipments discovered each week from December 6, 1938, to the end of the shipping season on April 15, 1939. The mortality of larvae, as shown by the examination of shipments after fumigation, is given in table 1. All examinations were made within 24 hours.

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1/ For the sake of clearness and brevity, dosage rates are hereinafter abbreviated similarly to the following: 4 lb. for 90 min. in a 15" vac. All dosages are in pounds of methyl bromide per 1,000 cubic feet of space.

Previous experience with methyl bromide fumigation had shown that insects might live several days after exposure before succumbing. Therefore, when mortality occurred within 24 hours it was assumed that the treatment was well over the minimum dosage needed.

Table 1.—Mortality of Maruca testulalis larvae in lima bean pods resulting from 90-minute fumigations with methyl bromide at the rate of 4 pounds per 1,000 cubic feet in a 15-inch vacuum, at dock temperatures, New York City, 1938-1939

Date	Temperature of pods, °F.	Number of hampers examined	Number of larvae		Mortality, percent
			Dead	Alive	
Dec. 6	51-57	40	30	0	100
14	41-45	43	16	0	100
21	40-45	21	1	0	100
28	50	11	3	0	100
Jan. 4	40-43	33	5	0	100
11	50	29	9	0	100
18	38	16	2	0	100
25	34-40	37	7	0	100

In February and March, 1939, further studies were made at San Juan, P. R., where an abundance of Maruca testulalis larvae were available. The results of these and the above-mentioned tests have been published[2/] and will be considered here only briefly.

Vacuum fumigations at temperatures between 75° and 85°.--Low dosages were found to be effective under vacuum conditions, as a rate as low as 0.5 lb. for 90 min. in a 15" vac. gave complete mortality, even in the centers of packed crates (see table 2).

Atmospheric fumigations at temperatures between 75° and 80°.—A 2-hour exposure at atmospheric pressure proved to be as effective as a 90-minute exposure in partial vacuum. A dosage as low as 0.5 lb. for 2 hr. at atmospheric pressure produced complete mortality.

Vacuum fumigations at temperatures below 70°.--A higher dosage was necessary at the lower temperatures. Survivals occurred after exposure to 1.5 lb. for 90 min. in a 15" vac. at 41°, but 2 lb. at 55° and 2.5 lb. at 41° gave complete mortality in one test each. (Table 2.)

2/Latta, Randall. Methyl bromide fumigation for destruction of pod borer larvae. Jour. Econ. Ent. 33 (1): 176-179. 1940.

Table 2.--Mortality of Maruca testulalis larvae in string beans resulting from 90-minute fumigations with methyl bromide in a 15-inch vacuum, San Juan, P. R., February 1939

Dosage (pounds per 1,000 cubic feet)	Temperature °F.	Number of larvae		Mortality, percent
		Dead	Alive	
Normal temperatures				
0.25	80	11	5	69
0.5	80	22	0	100
0.5	80	23	0	100
0.5*	77	51	0	100
1	80	23	0	100
1*	77	71	0	100
1.5	77	15	0	100
1.5	78	25	0	100
2	80	45	0	100
2	77	29	0	100
2.5	82	11	0	100
3	80	18	0	100
Low temperatures				
1	41	30	3	91
1	41	44	0	100
1	41	6	24	20
1.5	41	5	1	83
1.5	41	68	0	100
1.5	41	36	8	82
2	55	22	0	100
2.5	41	2	0	100

*Infested beans layered in the center of a loaded crate.

Later tests at Havana, Cuba, in December 1939 substantiated the results obtained at San Juan. These tests were made in an atmospheric fumigation vault (2,500 cubic feet capacity) as follows:

0.5 lb. for 2 hr. at 70-80°, empty vault--31 larvae, all dead.
1.5 lb. for 2 hr. at 70°, loaded hampers in empty vault--90 larvae, all dead.
1.5 lb. for 2 hr. at 70-80°, pods in exposed position in partially loaded vault--12 larvae, all dead.
1.5 lb. for 2 hr. at 70-80°, loaded hampers in center of loaded vault--4 larvae, all dead.
1.5 lb. for 2 hr. at 70-80°, pods in exposed position in fully loaded vault--13 larvae, all dead.

Host-Tolerance Studies

Green lima beans.—At New York City small lots of Cuban lima beans were fumigated with methyl bromide without injury, as listed in table 3.

These beans had been picked at least a week previously but had been under good storage conditions (50° F. or less) during the intervening time. The lots treated on November 30 were held in storage and shown on December 5 to a committee of bean importers, who were unable to distinguish between fumigated and untreated samples.

Table 3.—Results of experimental fumigations of green lima beans at New York City, 1938

Treatment					
Date	Dosage, pounds	Duration, minutes	Vacuum, inches	Temp., °F.	Results
Nov. 11	2	90	15	70	No injury.
	2.5	90	15	70	Do.
	3	90	15	70	Do.
	4	90	15	70	Do.
	2.5	120	none	70	Do.
Nov. 30	3	90	15	43	Do.
	4	90	15	43	Do.
	5	90	15	43	Do.
	4	90	25	43	Do.

At San Juan small lots of Puerto Rican green lima beans (freshly picked) were treated without injury, as shown in table 4. One-half of each sample was stored at room temperature, the other half in an electric refrigerator.

Some of the beans fumigated March 8, as listed in table 4, were shipped to New York City, then transported to Washington, D. C., where they arrived in good condition.

An additional series of lima beans fumigated with 3-lb., 4-lb., and 5-lb. dosages were sacked in tight paper bags soon after removal from the vault and stored in a household electric refrigerator. After 5 days they were apparently in good condition, but upon removal from the refrigerator they decayed rapidly. This was assumed to be due to failure to allow the pods to aerate well following fumigation before they were placed in the tight bags. The experiment was repeated, cheesecloth bags being used, and no injury occurred.

At Havana, Cuba, 16 hampers of freshly picked lima beans were fumigated, without other load, with 1.5 lb. for 2 hr. at atmospheric pressure at 70° on December 8, 1939. After airing, the beans remained in excellent condition for 8 days at precooling temperatures.

Table 4.—Results of experimental fumigations of green lima beans at San Juan, P. R., 1939

Treatment						
Date	Dosage, pounds	Duration, minutes	Vacuum, inches	Temp., °F.	Storage	Results
Feb. 24	1	90	15	75	room	No injury.
					refrig.	Do.
	2	90	15	77	room	Do.
					refrig.	Do.
	3	90	15	80	room	Do.
					refrig.	Do.
	4	90	15	82	room	Do.
					refrig.	Do.
	5	90	15	82	room	Do.
					refrig.	Do.
Mar. 8	2	90	15	77	refrig.	Do.
					ship*	Do.

*Shipped to New York.

String beans.—At San Juan, P. R., several tests were made with freshly picked string beans, as given in table 5. In one series a half of each sample was stored at room temperature, the other half in an electric refrigerator. In these tests increasing amounts of injury to pods were caused by dosages of 3 lb. and above, but with 2 lb. only very slight injury was caused in two trials, and none in two others. Two lots treated with 2 lb. were shipped to New York and arrived in excellent condition.

Table 5.—Results of experimental fumigations of string beans at San Juan, P. R., 1939

Treatment						
Date	Dosage, pounds	Duration, minutes	Vacuum, inches	Temp., °F.	Storage	Results
Feb. 17	3	90	15	77	room	No injury.
					refrig.	Do.
	4	90	15	77	room	Do.
					refrig.	Injury.
Feb. 21	2	90	15	71	ship*	No injury.
Mar. 2	2	90	15	79	refrig.	Slight injury.
	3	90	15	79	refrig.	Moderate injury.
	4	90	15	79	refrig.	Severe injury.
Mar. 8	2	90	15	77	ship*	No injury.
					refrig.	Very slight injury.

*Shipped to New York City.

Pigeon peas.— In San Juan one test was also made with freshly picked pigeon peas, in which one crate was fumigated on February 23 and shipped to New York with numerous untreated packages. A dosage of 2 lb. for 90 min. in a 15" vac. was used. There was little difference between the fumigated crate and the others when they were examined upon arrival at New York.

Commercial Application

Following the first trial fumigation of 274 one-bushel hampers of green lima beans on December 6, 1938, all infested shipments (a lot under one customs entry was considered a shipment) were allowed entry following fumigation and reinspection. This method was followed on weekly importations until January 25, 1939, after which the reinspection was eliminated since it had become apparent that the treatment was dependable. The shipping season, previously terminated on April 1, was extended for several weeks with the provision that all incoming pod vegetables be fumigated.

Up to April 1, 1939, 7,765 hampers of green lima beans were fumigated, and from April 5 to 19, 4,736 more were treated, a total of 12,501. During April 97 crates of pigeon peas were also fumigated in New York. The trade was well satisfied with the quality of both these products following fumigation.

When the next shipping season opened on November 1, 1939, the Bureau required the fumigation of all entries of green pod vegetables with a dosage of 3 lb. for 90 min. in a 15" vac. at prevailing temperatures. The shipments of lima beans from Cuba were fumigated at New York upon arrival during November, but it was soon realized that this would be unsatisfactory because of (1) cost, (2) overcrowding of existing facilities, and (3) delay in delivery for at least 2 days after docking. As a result, a fumigation plant was built at Havana, Cuba, with the intention of treating all beans before shipment. The Division of Control Investigations provided plans for the plant, and the writer tested the equipment when finished.

The plant was built by the Cuban American Terminal Company for the Asociacion de Cosecheros y Exportadores de Frutas y Vegetales de Cuba, and all fumigations were to be certified by the Seccion de Sanidad Vegetal de la Secretaria de Agricultura. It consisted of two atmospheric fumigation vaults of 2,500 cubic feet capacity, each capable of holding 936 hampers.3/

3/ Even though experiments in Puerto Rico had shown that atmospheric fumigation was as efficient as vacuum for the destruction of pod borer larvae, the use of the latter method was continued in New York, since equipment was available and the commercial procedure had already been established. However, for the purpose intended, atmospheric fumigation was preferred for use in Havana owing to the much lower cost of equipment.

Based on the data obtained at San Juan, a dosage rate of 1.5 lb. for 2 hr. at prevailing temperatures was recommended for treatments at Havana, which was calculated to be sufficiently in excess of the necessary minimum to care for variations in temperatures or other factors, and well within the range of host tolerance.

Under routine operation these vaults provided information on (1) prevention of sweating and (2) length of aeration period following fumigation.

It had been foreseen that sweating would be a problem owing to the confining of large quantities of freshly picked beans in an airtight vault. However, it was soon determined that heating was prevented if the circulating blower was operating from the time loading started, although sweating proceeded until the atmosphere was near or at saturation.

Frequent observations of partial and full loads in the vaults showed that temperatures equalized to the prevailing air temperature regardless of whether the hampers were above or below that point when loaded into the vaults.

It had been anticipated that the aeration period would take several hours, and this problem was considered a serious obstacle in perfecting a satisfactory commercial routine. However, actual working tests proved that a much shorter time was satisfactory. At the end of each fumigation an exhaust vent was opened, the door of which dropped in front of the blower used for circulation, thus directing all of its discharge to the outside of the vault. At the same time two intake vents at the opposite end of the vault were opened to admit fresh air to replace the air-gas mixture which was being ejected. The blower in each vault had a capacity of 1,100 cubic feet per minute. Tests were made with a halide leak detector of partial and full loads, and the rapidity of aeration was determined in this manner. Under prevailing temperature conditions (70° and above) it was determined that loads of 300 to 500 hampers were cleared of all detectable concentrations of gas in 2 hours, and loads of 600 to 900 in 3 hours. The free air in the vaults cleared in 45 minutes or less, so it was safe for the operator or workmen to enter, since the definite draft toward the exhaust vent carried away gas still disseminating from the fumigated hampers. Tight hampers (with no cracks between staves) often held a detectable quantity of gas for periods longer than indicated above, but dissemination from these occasional containers was such that the dilution with air surrounding them was sufficient to lower the concentration to undetectable amounts.

Other test loads were removed from the vaults before the hampers were free of gas but after the air surrounding showed no detectable concentrations. In normal handling about 1 hour elapsed between unloading and transfer to a precooler, and in all cases this period was sufficient to free all hampers of gas before entering refrigeration. In still other tests hampers still showing detectable amounts of gas were put in a precooler where cold air was forced through at a rapid rate. The moving air

carried away diffusing gas so rapidly that it was not detectable outside the hampers.

In the tests made at Havana, as well as in those previously made in New York, it was found that even though hampers contained gas concentrations as high as 100 to 150 parts per million, when they were placed in an exposed position, the gas removal was of a rate that allowed for very great dilution so that traces could be found only within a few inches of the package. This applied to large quantities of material as well as small. The observations indicated, however, that quantities of fumigated material should not be confined in closed quarters unless adequate ventilation is assured.

During the winter of 1939-40 the following quantities of imported green pod vegetables were fumigated either at New York or Havana, as indicated:

Green lima beans - -	14,770	hampers of Cuban origin at New York
	118	hampers of Puerto Rican origin at New York
	77,293	hampers of Cuban origin at Havana
Pigeon peas- - - - -	5,578	boxes of Puerto Rican origin at New York
String beans - - - -	31,667	hampers of Cuban origin at Havana
	1,471	boxes of Puerto Rican origin at New York

All the produce fumigated at New York was given a dosage of 3 lb. for 90 min. in a 15" vac. at temperatures mostly between 40° and 50°. All produce fumigated at Havana was given a dosage of 1.5 lb. for 2 hr. at atmospheric pressure at prevailing temperatures (70° to 90°).[4/] The large quantity of string beans imported was due to a high market following freezing weather in bean-growing areas of the southern states early in 1940.

All three of these products were kept under constant observation, and no injury or other lessening of quality was found. The writer tested many samples for taste and found no difference from untreated samples. The trade accepted these vegetables, and there have been no complaints of injury from them.

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[4/] See footnote 3.

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CIPOLLINI BULBS

Problem

Dormant bulbs of Muscari comosum, known in the trade by the name cipollini (meaning "little onion" in Italian), have been imported in quantity from Morocco for consumption as food. These bulbs were not cultivated, but were collected from mountainsides where they grew wild in great numbers. They were often infested with larvae of Exosoma lusitanica, a chrysomelid beetle not known to occur in the United States. Infestation was generally very light in bulbs imported during the early winter months, as they had been in storage for some time and evidently the larvae present had left to pupate. Soon after the beginning of a new year, however, so-called new-crop bulbs which had recently been dug began to arrive. These were usually moderately infested.5/

Until 1938 all infested shipments had been admitted only after a prescribed hot-water treatment of 3 hours at 114° F. Since practically all importations were made during the winter months, this treatment was unpopular for reasons of (1) extreme difficulty of drying quantities of bulbs under winter conditions in unheated warehouses, (2) cost due to excessive handling necessary in drying, and (3) high loss of bulbs in storage when cold weather prevented proper drying. The hot-water treatment was efficient as far as control of insect larvae was concerned, but owing to the reluctance of importers to use this method and the losses following its use, the Division of Foreign Plant Quarantines desired a less costly and more satisfactory treatment.

Insect-Mortality Studies

On November 25, 1938, the first tests were made with a few infested bulbs removed from an importation of cipollini. Four of seven larvae survived a fumigation with 2 lb. for 90 min. in a 15" vac. at 70°, and 4 of 5 larvae showed activity after 4 days following a fumigation with the dosage raised to 2.5 lb. Larvae of the narcissus bulb fly (Merodon equestris) present in the bulbs also survived these dosages.

Because of the scarcity of available larvae of Exosoma lusitanica, no further tests could be made at that time, so a dosage rate of 4 lb. for 2 hr. in a 15" vac. at 65° or above was arbitrarily selected for use in a test fumigation of 700 cases (25 to 30 tons). These bulbs were supplied by an importer desirous of using methods other than hot-water treatment, and were treated on December 5. The bulbs were warmed to

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5/ Kisliuk, M. Some Scientific Contributions Made at the Port of New York. Jour. Econ. Ent. 33 (2): 376, 1940.

approximately 75° before fumigation. Twenty-seven larvae of E. lusitanica and 17 of Merodon equestris were recovered from cases selected at random from the load, and all were dead within 48 hours, with bodies collapsed and partially or wholly discolored.

Only incidental recoveries of occasional dead larvae were made from many additional commercial fumigations at the above dosage rate until January 11, 1940, when a number of larvae were recovered from beneath stacked cases of fumigated bulbs. These larvae were active when collected but all died within a few days. A later recovery of over 50 larvae in a similar manner also resulted in complete mortality.

On January 13, 1940, about 10 active larvae were fumigated with 4 lb. for 4 hr. in a 15" vac. at 46-50°. All were killed.

Host-Tolerance Studies

At New York City small lots of imported cipollini bulbs were subjected to a series of fumigations with methyl bromide in November 1938. About 400 bulbs were used in each sample, as listed in table 6. These bulbs were kept under observation for 30 days or longer and showed no evidence of injury from treatment. Twenty-four bulbs from each of the first four treatments given in table 6 were planted in the laboratory greenhouse and forced during January and February. All lots grew and flowered normally.

It was assumed from these tests that the bulbs were very tolerant to methyl bromide fumigation, and it was on this assumption that a treatment of 4 lb. for 2 hr. in a 15" vac. at 65° or above was selected for commercial use.

Table 6.--Results of experimental fumigations of cipollini bulbs at New York City, 1938

Date	Treatment				Results
	Dosage, pounds	Duration, minutes	Vacuum, inches	Temp., °F.	
Nov. 25	2	90	15	70	No injury.
	2.5	90	15	70	Do.
	3	90	15	70	Do.
	4	90	15	70	Do.
	2.5	120	none	70	Do.
Nov. 30	3	90	15	43	Do.
	4	90	15	43	Do.
	5	90	15	43	Do.
	4	90	25	43	Do.

In November 1939 further experimental tests of bulb tolerance were made at Washington, D. C., in an attempt to establish the maximum dosages that could be used safely. The experiments tested increases of dosage, duration, and vacuum. The results of these tests are given in table 7.

Table 7.—Results of experimental fumigations of cipollini bulbs at Washington, D. C., November 24 and 25, 1939

Treatment				Decayed bulbs		Remarks
Dosage, pounds	Duration, hours	Vacuum, inches	Temp., °F.	Number found after 27 days	Additional number after 41 days	
4	4	15	70	0	0	
5	2	15	70	1	1	
6	2	15	70	0	0	
8	2	15	70	11/34*	4/23*	4/10 buds dead
5	4	15	45-50	2	0	
6	4	15	50-55	2	0	6/10 buds dead
4	2	15	90	0	0	
4	2	25	70	6/48	0	
4	3	25	70	3/70	0	
4	4	25	70	21/46	3/25	4/22 buds dead
0	-	-	-	0	0	

*First number denotes number of decayed bulbs out of total given by second number, i.e., 11/34 = 11 decayed bulbs out of a total of 34.

In the examination of the bulbs used in this series, all decayed ones were removed at the time, so that the number of decayed bulbs after 41 days in storage were in addition to the number after 27 days. It was observed that the checks and many of the treated bulbs showed considerable development of new buds in the neck region. In the severest treatments a number of these buds had been killed and discolored, and the remainder were still inactive. In direct association with this factor was a significant loss of bulbs from internal decay. Therefore, where both conditions occurred it was judged that treatment was responsible for injury.[6/] Where some loss of bulbs was noted but the remainder had well-developed new buds, the decay was considered as originating from external bruises or cuts.

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6/ In subsequent studies with new-crop bulbs it became evident that injury to the bud could not be used as a criterion of fumigation effect because of the extremely small size of the bud, since it was only in the formative state.

On this basis, then, two treatments were considered to have caused definite injury, namely, 8 lb. for 2 hr. in a 15" vac. at 70°, and 4 lb. for 4 hr. in a 25" vac. at 70°, while a third, 6 lb. for 4 hr. in a 15" vac. at 50-55°, was on the borderline in that buds were killed but no loss of bulbs followed. The remaining dosages were apparently all within the tolerance range of cipollini bulbs. This suggested a very safe margin between the recommended treatment and the maximum tolerance of the bulbs.

It must be pointed out that the above tests were made with "old-crop" bulbs, dug during the spring and summer and well cured before shipping. These bulbs were probably in their natural dormant period at this time, as evidenced by the presence of new flower buds in the bulbs. New-crop bulbs, which were apparently dug during the growing season, are in an abnormal condition and might exhibit a different degree of tolerance to fumigation treatments. Under routine commercial conditions, as will be shown in the following section, there was less loss from new-crop bulbs than from old-crop fumigated with the recommended dosage.

Commercial Application

Various importers of cipollini bulbs were anxious for an alternative treatment to the recommended hot-water immersion, so after the first series of experimental tolerance tests in November 1938 a lot of 700 cases was offered by an importer for an experimental large-scale treatment. As noted previously, a dosage rate of 4 lb. for 2 hr. in a 15" vac. at 65° or above was selected for trial. The bulbs were raised from a storage temperature of approximately 45° to 75° by placing the entire lot in the fumigating vault and applying heat through the medium of a steam coil in the bottom. This vault was a long cylinder of the type frequently used for vacuum fumigation. There was no circulation other than convection currents, and the temperature at the extreme top reached about 110°. The end doors were kept open to prevent sweating. In this instance the bulbs remained in this warm location for 3 days over a weekend.

Following fumigation, the bulbs were reexamined, and when all larvae were found dead the shipment was released from quarantine. Samples of bulbs saved from cases selected at random from this fumigation were kept under observation for several weeks and showed no apparent effect from the treatment. As soon as the trade was satisfied that no injury occurred, all subsequent infested importations were fumigated rather than treated in hot water. In the fiscal year 1938-39, 9,925 cases were fumigated.

During 1938, 1939, and January 1940 the recommended treatment required a bulb temperature of 65° or above. Practically all shipments, with the exception of two or three fumigated in the late spring of 1939, were heated as described above to meet this requirement. In most instances, if a shipment of bulbs was placed in the vault late in the afternoon, it would be warmed to 65° the following morning without the air temperature at the top of the vault going above 110°. This procedure was considered a benefit by most importers because of the drying of moist or moldy bulbs.

On January 24, 1940, the recommended treatment was broadened to allow fumigation at storage temperatures as follows:

4 lb. for 2 hr. in a 15" vac. at temperatures above 65°, or
4 lb. for 4 hr. in a 15" vac. at temperatures below 65°.

In the fall of 1939 certain importers suggested that fumigated bulbs did not store so well as untreated ones, although apparently there was no effect on quality. Therefore an intensive study of all shipments fumigated during the winter of 1939-40 was undertaken. Samples of treated and untreated bulbs were saved from each commercial fumigation and kept under observation at Washington, D. C., and, whenever possible, observations were made of lots in storage in New York City.

From November 1, 1939, until May 1, 1940, samples from 34 fumigated lots, representing 13,111 cases of bulbs, were kept under observation for approximately 1 month following fumigation. Each sample weighed about 4 pounds and contained from 40 to 65 or more bulbs, depending on their size. Nine of the 34 samples showed considerable loss during storage (see table 8), the remaining 25 samples keeping in excellent condition. Where two or three bulbs in a sample decayed, it was attributed to normal storage loss, since a similar loss occurred in some untreated samples. Of the 9 samples showing a high percentage of loss in storage, 1 was found to have much higher loss in the sample than in a part of the original shipment still in storage, and 2 more were from shipments frozen before treatment. Three of the remaining 6 lots belonged to one importer who received much cipollini from miscellaneous sources, and none of it was selected or graded.

Table 8.--Results of storage tests with samples from shipments of cipollini bulbs fumigated, 1939-40

Date	Number of cases fumigated	Number of decayed bulbs in samples		Remarks
		Untreated.	Fumigated	
1939				
Nov. 25		0	0	
Nov. 25	1,400	0	2/43*	
Nov. 27		0	15/42	
Nov. 27	850	3/50	3/52	
Nov. 29	100	7/48	1/45	
Nov. 29	200	----	14/53	
Dec. 1	520	0	65/80	60 cases in storage showed only 0 to 10% decay.
Dec. 1	200	1/47	22/68	
Dec. 4	150	2/54	0	
Dec. 12	566	0	0	
Dec. 13	500	0	0	
1940				
Jan. 5	300	1/51	10/45	
Jan. 9	2,100	0	1/54	
Jan. 10	100	0	0	
Jan. 13	100	0	29/40	
Jan. 22	400	0	0	
Jan. 26	132	0	46/49	Lot frozen on dock.
Feb. 7	443	40/49	47/47	Do.
Feb. 9	150	0	0	New-crop bulbs, arrived wet and moldy.
Feb. 9	300	0	0	Do.
Feb. 15	150	0	0	Do.
Feb. 16	50	0	0	Do.
Feb. 20	150	0	0	Do.
Feb. 20	200	0	0	Do.
Feb. 27	200	0	35/49	Do.
Mar. 8	400	0	0	
Mar. 19	200	0	0	
Mar. 19	200	0	0	
Mar. 19	200	0	0	Do.
Mar. 22	100	0	0	
Mar. 22	698**	0	0	Do.
Mar. 28	650**	0	0	
Apr. 18		0	0	
Apr. 24	1,302**	0	0	

*First figure denotes number of decayed bulbs out of total given by second figure.

**Treated without heating with 4 lb. for 4 hr. at 48°, 45°, 56°, and 58°, respectively.

A part of the stock treated on December 1 (520 cases), which showed a loss of 65 out of 80 bulbs in the sample, was located in storage and examined January 10. Sixty cases remained, stacked 5 high and 12 long in a single row. One stack was removed from near the center, and samples were taken from each case. The percentage of decayed bulbs varied from 0 to over 10 in the 5 cases. New buds in a number of bulbs cut open were in normal condition. Either the sample kept for observation had been selected from a case having a large amount of incipient decay, or else its storage conditions were unfavorable. The results of the examination were:

Top case-- 2 of 200 bulbs from two locations in case decayed (1%)
Second case-- 5 of 200 bulbs from one end of case decayed
Third case-- 12 of 112 bulbs from one end of case decayed (10.7%)
Fourth case-- 2 of 200 bulbs from one end of case decayed (1%)
Bottom case-- 0 of 200 bulbs from two locations in case decayed (0%)

In one shipment which had been frozen before treatment the loss was attributed definitely to that fact, since both treated and untreated samples decayed. In the other instance of bulbs frozen prior to treatment there was almost total loss in the treated sample but none in the check. This may have been due to the effect of heating the frozen bulbs.

The samples from shipments fumigated during November and December were selected at random before and after fumigation, whereas samples from those treated after January 1 were taken from the same case in each instance. The former method may have contributed to a chance selection of a sample from a case with high incipient infection.

It was indicated that old-stock bulbs may have been more susceptible to storage losses, since 8 of the 9 samples showing loss were from that type.

Therefore, with unexplained high storage losses in only 6 of 34 tests, it was assumed that fumigation with the recommended dosages did not cause injury to the bulbs or foster conditions contributing to storage decay.

CHESTNUTS

Problem

Imported chestnuts often have been infested with larvae of weevils (Curculio sp., formerly Balaninus) and with larvae of the European codling moth (Laspeyresia splendana), necessitating a disinfestation treatment. For several years infested nuts had been treated in hot water of 112° F. for 45 minutes. This treatment was expensive because of the excessive handling necessary when quantities of nuts were treated, and it offered the

same difficulties of drying during winter months as were encountered in hot-water treatment of cipollini bulbs. A less expensive and more rapid treatment, such as fumigation would provide, was desired for use on the Pacific coast for importations of Japanese chestnuts as well as in New York for an anticipated increase of shipments from Mediterranean countries.

Insect-Mortality Studies

No live specimens of either species of insects likely to be in imported chestnuts were available for use in experimental tests, so studies were made with larvae of the native chestnut weevils Curculio proboscideus and C. auriger. The following recommendation for treatment of imported chestnuts was based on these experiments:

Above 70°--4 lb. for 2 hr. in a high sustained vacuum (25" or more)
Between 50° and 70°--4 lb. for 4 hr. in a high sustained vacuum
Below 50°--4 lb. for 5 hr. in a high sustained vacuum

In chestnuts examined following treatments of commercial shipments fumigated with the above schedule it was found that all Laspeyresia splendana larvae were destroyed.

Host-Tolerance Studies

Brief tests to determine the effect, if any on the quality of chestnuts were made in 1938 at Washington, D. C. On November 22, chestnuts purchased on the open market were divided into lots of 12 nuts each and fumigated with dosages of 2.5, 3, 3.5, and 4 lb., all for 90 min. in a 15" vac. at approximately 70°. The chestnuts were examined by C. A. Reed, of Nut Investigations, Bureau of Plant Industry, and no change in taste or quality could be detected.

On December 15, further tests were made with Italian chestnuts (Castanea sativa). Dosages of 3, 4, and 5 lb., all for 2 hr. in a 15" vac. at 75°, and 3 lb. for 2 hr. in a 25" vac. at 75° were used. These chestnuts were also examined by Mr. Reed, and no effect to taste or quality could be detected.

During 1939 more extensive tests were made at Washington with American-grown chestnuts of Castanea mollissima (Chinese), C. crenata (Japanese), and various hybrids of each. Early- and late-maturing strains of each were tested, as well as immature (nuts just dropped) and mature (nuts held about 2 weeks until sweet) samples of each. In all, 31 samples were treated. Dosages up to the following limits were tested:

4 lb. for 3 hr. in a 15" vac. at 70°
7 lb. for 90 min. in a 15" vac. at 70°
6 lb. for 2 hr. in a 27" vac. at 70°
4 lb. for 3 hr. in a 27" vac. at 60°
5 lb. for 3 hr. at atmospheric pressure at 70°

All the samples were examined by Mr. Reed for taste and quality, and no change could be detected.

Commercial Application

Importers of chestnuts showed no reluctance in accepting methyl bromide fumigation in lieu of hot-water treatment. Starting with a shipment of 118 kegs on November 1, 1939, 8,316 containers (baskets, boxes, and kegs), mostly of Portugese origin, were fumigated during November, December, and January, at New York City, and 940 containers of Japanese chestnuts at Seattle, Wash.

Some of the shipments of chestnuts were heated before fumigation in order to take advantage of the shorter exposure period, and others were fumigated at storage temperatures between 40° and 60°.

Samples saved from 13 fumigated shipments were kept under observation at Washington, D. C. In no instance was there any increase in loss during storage, nor was there any effect on taste or quality.

Two shipments consisting of several hundred baskets, which had been fumigated on December 22, were examined in storage on January 10 and were in almost the same condition as at the time of arrival.

CHILEAN PEACHES

Problem

A shipment of Elberta peaches from Chile was found infested with live adults of Pantomorus sp., a close relative of the white-fringed beetle. An emergency treatment was needed for this shipment.

Commercial Application

Because peaches had been successfully fumigated with methyl bromide in previous tests, the importer offered the shipment for experimental treatment without preliminary trials in this instance. The entire lot of 606 boxes was fumigated with 3 lb. for 90 min. in a 15" vac. at 38-40° on February 17, 1940. The fruit was green. The adults of the white-fringed beetle are known to be killed at normal temperatures with very low dosages of methyl bromide, therefore for this closely related species the selected rate was considered to be well in excess of the amount needed after the effect of a low temperature and the use of vacuum had been calculated.

Samples of untreated and fumigated peaches were retained and observed for several days to study any effect that might result from fumigation. Both samples ripened normally and showed no effect on either taste or quality. Later reports were that the peaches moved through commercial channels without any report of injury.

ARGENTINE GRAPES

Problem

A shipment of five varieties of grapes arriving in New York from Argentina were found infested with live adults of Pantomorus sp. An emergency treatment was needed for this shipment.

Host-Tolerance Studies

The infested shipment was allowed to move from the piers to a bonded cold-storage plant. On March 7 several boxes of grapes of the varieties Thompson Seedless, Pizzutello, Black Olivet, and Ribier, all of the so-called soft type, were removed and subjected to experimental fumigations at the storage plant. The following tests were made, all at atmospheric pressure:

3 lb. for 2 hr. at 50°
4 lb. for 2 hr. at 50°
5 lb. for 2 hr. at 50°

Each sample was divided, one half going back into storage at 34°, the other half being placed in an open storeroom at 60-70°. On March 11 all samples were observed by a committee of grape importers and experts, who could not distinguish between untreated and fumigated samples in either those kept at room temperature or those kept in storage.

Commercial Application

On March 12, 2,432 boxes of grapes were removed from storage and fumigated with a dosage of 3 lb. for 2 hr. at atmospheric pressure at 50°. (The duration was extended to 2 hr. to compensate for the increase in pressure to normal atmospheric instead of partial vacuum as used in the treatment of peaches.) The grape temperature rose from 34° to approximately 50° during transit to the fumigating plant. The treatment was performed in a vacuum vault but no vacuum was used at any point in the procedure. The grapes were removed from the plant after a sufficient airing period and taken directly to a fruit auction, where they were sold. Later reports were that no bad effects resulted from the fumigation, but that the quality was somewhat lowered by the changes in temperatures and subsequent condensation of moisture on the fruit.

SUMMARY

Several types of imported perishable food products have been successfully fumigated with methyl bromide during the past 2 years to free them of certain insect pests. Data of experiments for destruction of these insects, tolerance of hosts, and commercial application are given.

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In tests made in Puerto Rico, larvae of Maruca testulalis were all killed by dosages of 0.5 lb. of methyl bromide per 1,000 cubic feet of space under either vacuum fumigation conditions for 90 minutes or atmospheric conditions for 2 hours. Green lima beans were found to be uninjured by dosages as high as 5 pounds at 70° or above. String beans and pigeon peas tolerated dosages of 2 pounds.

Fumigation of green pod vegetables was applied commercially under high-temperature conditions in Havana, Cuba, and under low-temperature conditions at New York City, with dosage rates of 1.5 lb. for 2 hours at atmospheric pressure, and 3 lb. for 90 min. in a 15" vac., respectively. In 1938-39, 12,501 hampers of green lima beans and 97 boxes of pigeon peas were fumigated, and in 1939-40, 92,181 hampers of lima beans, 5,578 boxes of pigeon peas, and 33,138 hampers of string beans.

Larvae of Exosoma lusitanica infesting cipollini bulbs were found to be killed by a dosage of 4 lb. per 1,000 cubic feet for 2 hours above 65° or for 4 hours below 65°. Cipollini bulbs proved to be very tolerant to methyl bromide fumigation. Fumigation of cipollini bulbs was applied commercially, and in routine fumigations 9,925 cases were treated in 1938-39 and 23,670 cases in 1939-40.

Chestnuts were also found (in experimental tests) to be very tolerant of methyl bromide fumigation as far as taste and quality were concerned. In the commercial application of this fumigation, 9,256 packages of chestnuts were fumigated in 1939-40.

One commercial fumigation each of Chilean peaches and Argentine grapes was performed without injury to the fruits.